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Astrophysics

COROT

The COROT satellite has been in operation since the end of 2006. Its purpose is to probe the structure of stars and to search for extrasolar planets by measuring tiny variations in the light output from the stars.
COROT has discovered hundreds of exoplanet candidates, among which 25 have been confirmed and characterised (Fig. 1). Many of these planets are strange objects, shedding new light on the formation and evolution of planetary systems: COROT-7b was the first confirmed super-earth; COROT-16b, COROT-20b and COROT-23b are hot Jupiters with unexpectedly eccentric orbits and exhibiting an unexplained range of densities. The precise characterization of Solar-like oscillations in various stars has been achieved for the first time, revealing phenomena hitherto out of reach. The seismology of red giants started with COROT and is now one of the most promising and active fields, with applications in galactic evolution. In addition to oscillations, the COROT data has revealed the signature of various phenomena which are now actively being studied: granulation, activity, and the mapping of inhomogeneities on stellar surfaces. The COROT operations and data processing activities are under the responsibility of CNES, LESIA in Paris, IAS in Orsay, LAM in Marseille and OMP in Toulouse.

HERSCHEL

In operation since 2009, the ESA far-infrared observatory HERSCHEL is the largest of the space telescopes. French laboratories, supported by CNES, play important roles in the data processing. HERSCHEL has revealed that the filamentary structure of the interstellar medium, the seat of stellar formation, is linked to sonic booms with their origins in supernovae explosions. It also detected for the first time the O_2 molecule in the interstellar medium, and provided, together with the XMM-Newton satellite, a fascinating new composite image of thefamous Eagle nebula, also known as the 'Pillars of Creation' (Fig. 2).

PLANCK

ESA's PLANCK mission, launched in 2009, is the most recent mission to map the Cosmic Microwave Background, or CMB – the radiation left over from the Big Bang. The Early Release Compact Sources Catalog issued in January 2011 provided the scientific community with about ten thousand submillimetre sources, many of which had never been detected. It included about 200 galactic clusters and hundreds of pre-stellar objects. In February 2012, French teams issued the first all-sky CO map (Fig. 5). As anticipated, the High Frequency Instrument (HFI, developed by IAS with CNES support), ran out of ^{3}He coolant in January 2012. Although the coolant ran out, the nominal life had nevertheless been doubled, allowing 5 full sky surveys instead of 2 as initially planned for. For 2.5 years, the 100 mK HFI focal plane had been the coldest known point in space. A one year additional phase using only the Low Frequency Instrument is ongoing, with publication of the CMB results expected at the beginning of 2013.

James Webb Space Telescope/MIRI

MIRI (Mid-Infrared Instrument) is a spectro-imaging instrument with a coronographic mode developed by a consortium of European laboratories, among which are several French ones supported by CNES. It will be a key component of the JWST mission, in particular in the field of stellar discs and exoplanet studies. MIRI, a part of the European contribution to the JWST, will be delivered to NASA by the end of 2012.

GAIA

The ESA GAIA mission will measure the position and velocity of one billion objects in our galaxy to an accuracy of a few millionths of a degree.
Scanning the whole sky will also provide an invaluable database of spectroscopic data for small objects in the solar system, stars, galaxies and exoplanets. It will be launched in 2013 on a Soyuz rocket from Kourou. More than 400 people from European laboratories, coordinated by OCA, are currently involved in the challenging GAIA ground segment development. System-level tests in particular started at the French Data Processing Center developed by CNES.

SVOM

SVOM is a French-Chinese mission dedicated to the study of Gamma-Ray Bursts (GRBs) – the highest energy phenomena observed in the Universe.
Launch is expected in 2017. SVOM will provide unprecedented multi-wavelength monitoring of the GRBs, especially very distant ones. Through CNES, CEA/SAP and IRAP laboratories, France is responsible for the wide-field X-ray and gamma-ray camera ECLAIRs, the soft X-ray telescope, and the fast space-to-ground alarm transmission system.

Euclid

Euclid was selected in October 2011 as an ESA medium range mission dedicated to the study of dark matter and dark energy. These unknown components, which make up 20% and 76% respectively of the content of the universe, question the validity of Einstein's General Relativity at cosmological scales. Scheduled for launch in 2019, Euclid will address these questions by mapping large scale structures and probing the shapes of galaxies (Fig. 4). The Euclid survey will provide unique legacy science in various fields of astrophysics, from the detection of exoplanets and the stellar physics of our Milky Way to the formation and evolution of the galaxies. French laboratories at CNRS and CEA, supported by CNES, are leading the international effort in developing the Euclid instrumentation.

The Cosmic Vision "M3" candidates

• PLATO, ECHO and LOFT are candidates for the next ESA medium-sized mission in 2024. French laboratories supported by CNES are playing a major role in all these missions.

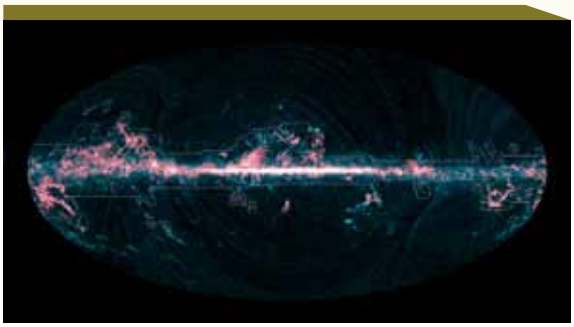
• The aim of PLATO is to detect and fully characterise planetary systems of all kinds including Earth-like planets around solar-like stars by means of the precise, continuous photometry of such stars.

• ECHO will characterise the chemical composition and physical properties of the atmosphere of about 200 transiting exoplanets using spectroscopic measurements of the starlight being filtered by the planetary atmosphere during the transit.

• LOFT will study the pulsating Universe, including pulsars, magnetars or X-ray binaries, using the combination of a unique 12 m^2 effective area, and precise timing and spectroscopic capabilities.

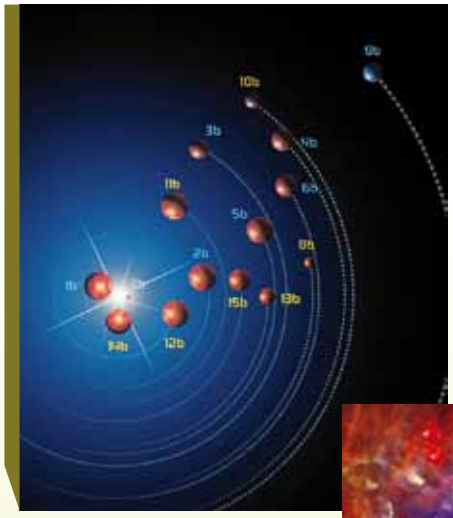
SPICA

The post-HERSCHEL SPICA JAXA mission will provide information about the formation and evolution of galaxies, stars and small bodies such as planets, comets or asteroids. Several French laboratories, supported by CNES, are participating in the ongoing SAFARI spectro-imaging instrument definition phase.

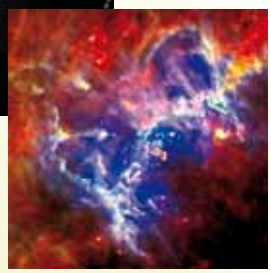


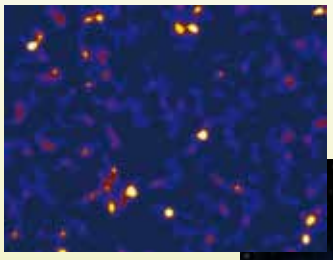
[Fig. 5]

[Fig. 1]



[Fig. 2]





[Fig. 3]

[Fig. 4]

ATHENA

The Advanced Telescope for High Energy Astrophysics is a next-generation X-ray ESA observatory (Fig. 4), and is a successor to the IXO studies carried out with NASA and JAXA. It will address some of the most fundamental questions in contemporary astrophysics and cosmology, such as black holes and matter under extreme conditions, formation and co-evolution of galaxies and their central black holes, clusters and large-scale structures, and the life cycles of matter and energy. For this purpose ATHENA will rely on spatially resolved high-resolution spectroscopy, along with accurate timing capabilities. French laboratories CESR and CEA/SAP, supported by CNES, are involved in the ATHENA instrumentation studies.

[Fig. 1] - Portrait of the COROT first 15 exoplanets. © Patrice Amoyel

[Fig. 2] - Stunning new Herschel and XMM-Newton image of M16 galaxy. Combining almost opposite ends of the electromagnetic spectrum, this composite of the Herschel in far-infrared and XMM-Newton's X-ray images shows how the hot young stars detected by the X-ray observations are sculpting and interacting with the surrounding ultra-cool gas and dust, which, at only a few degrees above absolute zero, is the critical material for star formation itself. © far-infrared: ESA/Herschel/PACS/SPIRE/Hill, Motte, HOBYS Key Programme Consortium; X-ray: ESA/XMM-Newton/EPIC/XMM-Newton-SOC/Boulanger

[Fig. 3] - Dark matter map computed with the "weak lensing" method, one of the Euclid probes. This method is based on the distortion of the galaxies due to the gravitational bending of light. © Van Waerbeke, Heymans, and CFHTLens collaboration

[Fig. 4] - This artist's impression depicts the ATHENA spacecraft. ATHENA is a candidate L-class mission in ESA's Cosmic Vision programme. © ESA

[Fig. 5] - PLANCK all-sky CO map. CO clouds appear in blue. Former surveys (Dame et al., 2001) are superimposed in pink. Contours of these surveys are indicated. © ESA/PLANCK Collaboration; T. Dame et al., 2001

AUTHOR: N. Aghanim [1] on behalf of the Planck collaboration

Astrophysics

Laboratory contribution

The first SZ-cluster sample of Planck

Le premier catalogue d'amas de galaxies de Planck

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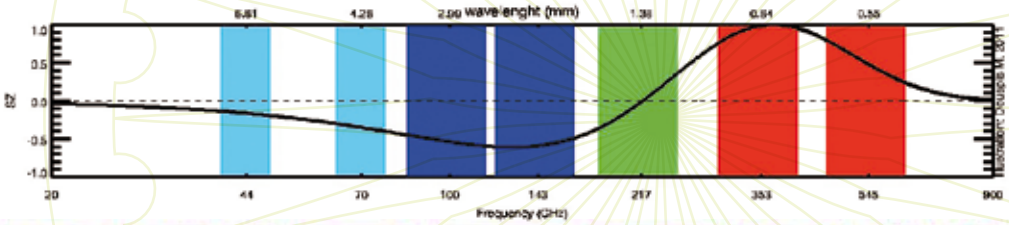
Abstract

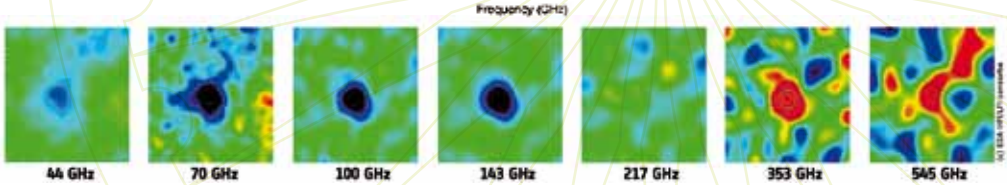
Galaxy clusters are detected by the Planck satellite through the Sunyaev-Zeldovich (SZ) effect from its six highest frequencies. To date, Planck has delivered ~210 SZ clusters in total including ~40 brand new SZ detections confirmed as single clusters or multiple systems. We present the first all-sky SZ sample (Planck Early SZ sample, ESZ) together with a preview of the properties of the Planck clusters and the scaling relations between SZ and X-ray or optical.

Résumé

Les amas de galaxies sont détectés par le satellite Planck grâce à l'effet Sunyaev-Zeldovich (SZ). Planck a fourni à la communauté un ensemble de ~210 amas de galaxies dont ~40 nouvelles détections SZ confirmées comme des amas individuels ou des systèmes doubles, voire triples. Nous présenterons le premier catalogue d'amas tout-le-ciel fourni par Planck ainsi que les premières conclusions sur les propriétés des nouveaux amas de galaxies de Planck et sur les relations d'échelles.



[Fig. 1 - haut]



[Fig. 1 - bas]

Clusters and SZ effect

Clusters of galaxies are the largest virialized objects of the Universe. Their baryonic content is dominated by a hot ionized intra-cluster medium, ICM, (~15%) responsible for the X-ray emission and the Sunyaev-Zeldovich (SZ) effect [1].

The SZ effect emerges when Cosmic Microwave Background (CMB) photons scatter off electrons of the ICM. The SZ effect has a specific spectral signature, showing up as brightness decrement at below 217 GHz and an increment above 217 GHz. The frequencies of Planck were specifically chosen to detect the SZ effect [2]. Figure 1 shows a cluster as seen by Planck. Note the negative (resp. positive) signal below (resp. above) 217 GHz where the effect is null.

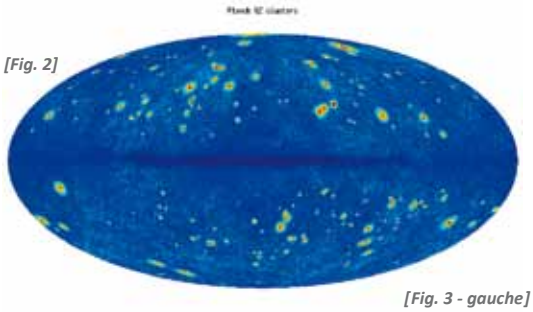
Planck clusters and the Early SZ sample

One of Planck's first product from the first ten months of observation is the Early SZ Cluster sample [3] (ESZ) as part of the Early Compact source Catalogue (Fig. 2).

Planck SZ clusters are detected using a matched multi-filter method [4] taking advantage of the SZ signature and of a spatial template (universal spherical pressure profile from [5]). This minimizes the contamination from foregrounds (Galaxy, radio/IR sources) and backgrounds (e.g. CMB). To attain the level of reliability required for the ESZ only high signal-to-noise ratio (S/N>6) clusters were published. Moreover a validation was performed to remove false detections, identify known clusters and list the candidate new clusters. It proceeded in two steps: (1) Internal cross-checks (cold cores, solar system objects, bad pixels), (2) cross-checks with existing X-ray and optical cluster catalogues and ancillary data (e.g. SDSS).

The ESZ contains 189 SZ detections with S/N>6, 188 are confirmed clusters, including 169 known and 19 brand-new Planck clusters. Eleven of the new clusters were confirmed by our XMM-Newton follow-up programme [6]. All the remaining new clusters, but one, are now confirmed with SPT, AMI, BOLOCAM and CARMA.

The ESZ provides a well defined sample of the most massive clusters at low redshifts.



[Fig. 2]

As a matter of fact, 86% of the ESZ clusters have z<0.3 and their masses span more than a decade up to 1.5 10^{15} M_{sun}.
This first product confirms Planck's unique capability of detecting the rarest and most massive clusters over the whole-sky.

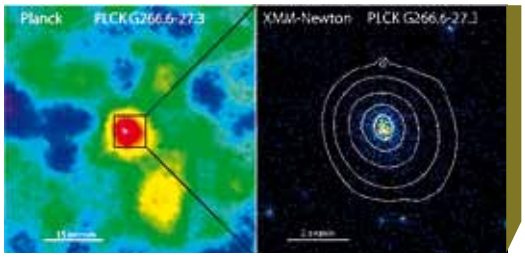
The new Planck clusters

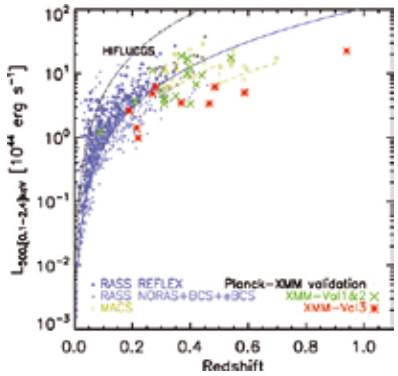
Planck has delivered a total of 39 brand-new SZ detections. Eight were confirmed independently from our Collaboration. The remaining 31 detections were confirmed with our XMM-Newton validation programme [6]. They include single clusters and double or triple systems with 4.5<S/N<10.6; most of them massive (> 9 10^{14} M_{sun}). The XMM-Newton confirmation shows Planck capability to detect cluster up to high z (first detection by Planck at z~1, Fig. 3 left) in a wide range of masses, and below RASS limits (Fig. 3 right). Moreover, Planck seems to detect an additional population of clusters missed by X-ray surveys. They have shallower density profiles than X-ray clusters of similar masses and are thus under-luminous in X-ray. They exhibit more complex morphologies.

Scaling relations

We studied the relation between SZ signal and X-ray luminosity on one side and optical richness on the other side [7] using two cluster catalogues in X-rays (MCXC) and in optical (MaxBCG). From these catalogues and using the universal pressure profile, we computed the expected SZ signal and compared it with the observed signal by Planck. We find that the Planck SZ signal is detected to the lowest masses (~5 10^{13} M_{sun}) and that the predicted signal from X-ray luminosity is in perfect agreement with Planck observations at all masses (luminosities). The SZ signal and the optical richness correlates well. However, the expected signal inferred from the richness is larger than the observed. This disagreement seems to be mostly due to selection effects as shown by [8].

[Fig. 3 - gauche]





[Fig. 3 - droite]

Conclusions

Planck has delivered ~210 clusters including ~40 brand new SZ detections confirmed as single clusters or multiple systems. The ESZ is a unique well-defined all-sky sample of 188 clusters. It is the most complete and homogeneous sample of massive SZ clusters at z<0.5. Planck's next release, early 2013, will significantly increase this catalogue. With Planck cluster catalogues we will have a unique dataset opening a new observational window for the study of galaxy clusters both as individual sources and as statistically representative population tracing the evolution of our Universe.

[Fig. 1] - Abell 2319 seen by Planck.

[Fig. 2] - Planck ESZ clusters on the sky (signal amplified for better visualisation).

[Fig. 3] - Left: Planck map of PLCKG266.6-27.3 (z~1). Middle: XMM-Newton image. Right: Planck-discovered clusters (red & green) compared to clusters from RASS catalogues [4,5].

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AUTHORS: F. Motte [1] - T. Hill [1]

Astrophysics

Laboratory contribution

The 'Pillars of Creation' as observed by Herschel

Les « pilliers de la Création » observés par Herschel

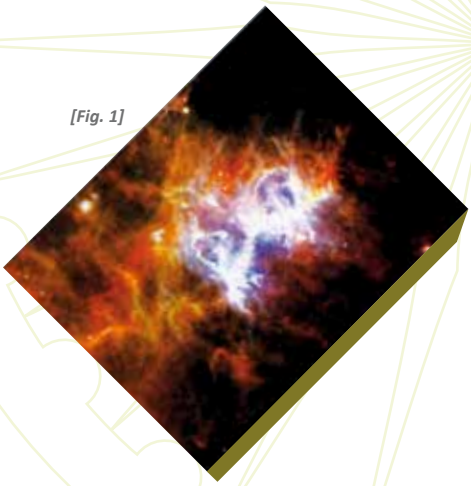
[1] CEA

Abstract

We present Herschel Space Observatory observations of the Eagle Nebula (M16) in the far-infrared and sub-millimetre. M16, home to the Pillars of Creation, is largely under the influence of the nearby NGC 6611 cluster. Herschel reveals a dust temperature gradient running away from the cluster which could impact the evolutionary state drawn for nearby star-forming cores. We also discuss the possible filamentary origin of this cluster, and a supernova remnant scenario presented in the literature.

Résumé

Nous présentons des observations de la nébuleuse de l'aigle (M16) dans l'infrarouge lointain et le sub-millimetrique grâce au télescope spatial Herschel. M16, hôte des pilliers de la Création, est fortement sous l'influence de l'amas voisin NGC 6611. Herschel révèle un gradient de température s'éloignant de l'amas et qui pourrait influencer l'état d'évolution qui se dessine pour les coeurs des étoiles voisines en formation. En outre, nous discutons l'origine possible de l'amas au sein d'un filament, et un scénario d'un vestigede supernova présenté dans la littérature.



[Fig. 1]

High-mass stars (with a mass greater than eight times the mass of the Sun) form in dynamic environments where they have a profound impact on their immediate surroundings, possibly even triggering the formation of new stars and planetary systems. The Herschel Imaging Survey of OB Young Stellar objects (HOBYS, [1]) targets the natal environment of nearby young high-mass stars to investigate their impact on cloud formation. The Eagle Nebula (also known as M16) is a young active high-mass star-forming region covered by HOBYS, which is home to the iconic Pillars of Creation (see Fig. 1). The Pillars of Creation, ~ 2 kpc from the Sun (~ 6 500 light years), have previously been observed with the Hubble and Spitzer Space Telescopes and with many other ground-based telescopes. Adjacent to the Pillars of Creation and responsible for heating and ionising the Eagle Nebula is the young open star cluster NGC 6611. This cluster contains four early type O stars and is associated with the cluster of a B2.5I star. The total mass of the cluster is 2 x 10^4 Mstar, and it is thus expected to have a strong influence on the nearby cloud structure through stellar winds and radiation. See [2] for more on M16 and the Pillars of Creation.

Recent Herschel observations, in the far-infrared and submillimetre, have shown the ubiquity of filamentary structures in both low [3] and high-mass [4] star-forming regions. These filaments appear to be the birthplaces of the next generation of stars, and high-mass stars appear to preferentially form in the high-column density supercritical examples of them [4]. Herschel HOBYS observations of M16 [2] have revealed a clear dust temperature gradient running away from the centre of the cavity carved out by the NGC 6611 cluster (Fig. 1). These observations also identified the filamentary structure in this region, in particular two prominent filaments, the Eastern and Northern Filament, which originate close to the NGC 6611 cluster (within 5 pc) and extend away from the cluster (Fig. 2). We investigated the impact of the cluster, with respect to heating, on these two prominent filaments.

The dust temperature within the filaments was measured as a function of distance from the cluster. The dust temperature profiles of these two prominent filaments indicate that NGC 6611 is able to heat M16 to a projected distance of 8-10 pc. The M16 cloud displays ~ 1.5-5 K temperature variations which corresponds to a heating gradient of 0.25-0.6 K/pc.

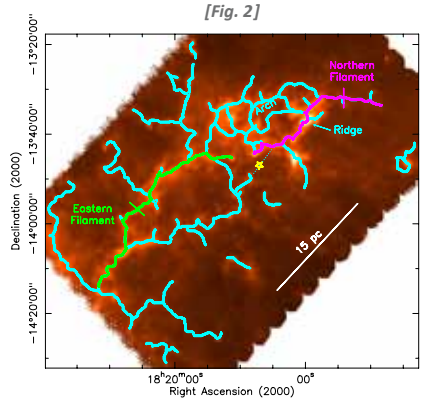
The Pillars of Creation themselves display a decreasing column density profile with increasing distance from the cluster, and thus an increasing dust temperature profile. They are likely early sites of star formation, in which turbulence rather than gravity is shaping the cloud [2].
The heating effect of the NGC 6611 cluster is not the same in all directions, which may arise if the cluster is not at the same distance as all of the features seen in Fig. 1. Alternatively, the ionisation and heating depths of the cluster may simply depend on the amount of material in the way, and thus the column density.
Such external heating, i.e. from nearby OB (high-mass star-forming) clusters, is often not considered when deriving the evolutionary status of a core from its far-infrared SED. Evolution/age proxies, such as L_submm/L_bol [5] or T_bol [6] have been recently extrapolated to massive dense cores [e.g. 7]. However, this should be done with caution, since massive dense cores generally form in molecular cloud complexes associated with OB clusters. By ignoring this effect, these parameters will appear to increase with distance from the cluster, giving the incorrect impression of triggered star formation, where sources close to the cluster will appear more evolved than those further away.

We also detected a filament that runs parallel to the Eastern Filament (Fig. 2) and extends up toward the Northern Filament [2]. Extrapolating this filament, it would extend up and join the Northern Filament at the approximate location of the NGC 6611 cluster. In this scenario, this filament was once the home to NGC 6611 before it evolved and formed high-mass stars. These high-mass stars then likely destroyed any continuation to the Northern Filament and instead carved the cavity around the cluster that we see with Herschel.

[Fig. 1] - Three-colour image of M16 (70, 160, 250 µm) as seen by Herschel. The Pillars of Creation and the cavity carved by NGC 6611 are clearly visible. As a proxy, the hot regions in this map appear blue, while colder regions appear red.

[Fig. 2] - (left) Column density image of M16 with the filamentary structure, including the prominent Eastern and Northern filaments, overlaid.
(right) Dust temperature profiles as a function of projected distance from the cluster;
(top) Eastern Filament. (Bottom) Northern Filament.

[Fig. 2]



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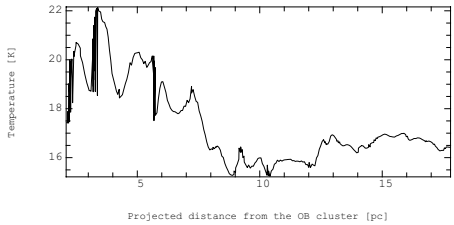

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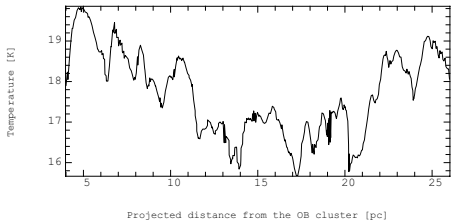

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Unusually hot dust seen with Spitzer toward M16 was attributed to a recent supernova explosion [8]. The dust temperatures that we detect [2] are in line with what is seen in other nearby high-mass star-forming regions. Additionally, both young, and old, supernova remnants have been readily detected by Herschel [9]. The fact that we do not see such evidence of a supernova remnant in our individual Herschel maps, and that we see no evidence of impact on the column density distribution around the NGC 6611 cluster, combined with an absence of evidence in the Spitzer images does not favour the presence of a supernova remnant in this region.

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Astrophysics

Laboratory contribution

A Cocoon of Freshly Accelerated Cosmic Rays Detected by Fermi in the Cygnus Superbubble

Un cocon de rayons cosmiques accélérés détectés par Fermi dans la super bulle de Cygnus

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Abstract

The Fermi Large Area Telescope (LAT) has unveiled a piece of the puzzle of cosmic-ray origin.
It has captured the γ-ray signal of young cosmic rays spreading in the turbulent interstellar environment of massive stars, near the bright Galactic stellar clusters of Cygnus X [1].
The 50-pc wide cocoon of energetic particles provides a first example to study the youth of cosmic rays within a superbubble environment before they diffuse at large in the Galaxy.

Résumé

En captant l'émission γ de jeunes rayons cosmiques se propageant dans l'environnement interstellaire turbulent d'étoiles massives, près des brillants amas stellaires de Cygnus X [1], le Large Area Telescope de Fermi a mis à jour une pièce du puzzle sur l'origine des rayons cosmiques. Le cocon de particules énergétiques, de 50 pc de large, fournit un premier exemple d'étude de la jeunesse des rayons cosmiques dans l'environnement d'une superbulle, avant qu'ils ne diffusent dans la Galaxie.

The origin of Galactic cosmic rays is a century-long puzzle. Indirect evidence points to their acceleration by supernova shockwaves, but we know little of their escape from the sources. The medium surrounding the core-collapse supernova progenitors is filled with supersonic turbulence, thus particle confinement and re-acceleration by repeated shocks can substantially modify the cosmic-ray (CR) properties before they diffuse at large in the Galaxy [2][3]. This early diffusion near clusters of massive stars can be followed in γ rays as the young CRs interact with the ambient gas and radiations.

The Fermi Large Area Telescope (LAT) has observed the star-forming region of Cygnus X that boasts an abundance of massive stars born in the past few million years in numerous clusters [4] (e.g. Cyg OB2 and NGC 6910 at a distance of ~1.4 kpc). The bright clusters have sculpted their parent clouds over tens of parsecs [5]: the compressed edges along the ionization fronts brightly shine in mid-infrared as photon dominated regions (PDRs) (Fig. 1).
The 1-100 GeV images taken by the LAT reveal a significant (10 σ) and well-resolved excess of hard γ rays (Fig. 1) above the emission produced by the old Galactic CRs and by known sources [1][6].

The excess peaks toward massive-star clusters and its morphology distinctly follows the regions bounded by PDRs, as in a cocoon. Stellar clusters can host γ-ray sources, but the excess properties and its spatial relation with PDRs point to an interstellar origin rather than to a set of unresolved sources. Overlooked gas in any state, irradiated by the old Galactic CRs, cannot explain the hardness of the cocoon emission. The latter extends to 100 GeV, and possibly to 10 TeV (Fig. 2). The 1-100 GeV luminosity of (9 ± 2) 10^{27} W at 1.4 kpc represents ~ 0.03 % and ~ 7 % of the stellar wind power in Cyg OB2 and NGC 6910, respectively.

To reproduce the LAT data with pure hadronic emission, we need a harder CR spectrum than near the Sun, with an amplification factor of (1.6-1.8) × $(E/10\ \mathrm{GeV})^{0.3}$ in proton and helium spectra and a total energy of 1.3 10^{42} J above 2 GeV/nucleon [1]. The region is filled with intense stellar light and infrared emission from heated dust.
CR electrons can upscatter these radiation fields to γ rays, but the resulting emission is too faint and too soft to match the data (Fig. 2). We need a harder electron spectrum than near the Sun, with an amplification factor of 60×$(E/10\ \mathrm{GeV})^{0.5}$ and a total energy of 4 1041 J above 1 GeV [1].

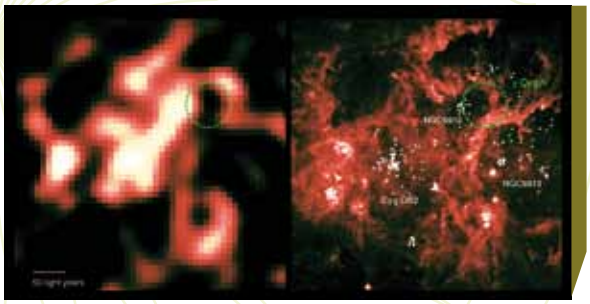
The hardness of the γ radiation points to freshly accelerated particles since the lifetime of TeV electrons is < 20 kyr in the cocoon and the escape time for > 0.1 TeV nuclei is < 50 kyr for the average Galactic diffusion coefficient [1].

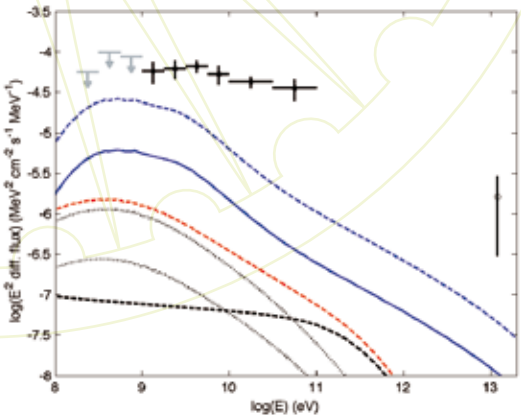
Where is/are the accelerator(s)? The 7-kyr-old supernova remnant of γ Cygni [7] is a potential candidate since it still shelters energetic particles shining in γ rays [1]. Its present expansion characteristics and CR acceleration models show that it could have produced and released CRs with high enough energies to explain the LAT data [1]. Yet, its relation to the Cygnus X cavities is unclear and the anisotropy of the cocoon emission around the remnant challenges this scenario since there is no evidence for a 'champagne flow' advecting particles out on the eastern rim. In the absence of advection, the short diffusion lengths expected in the turbulent medium of Cygnus X may rule out the very young γ Cygni as the unique accelerator in the region.

OB associations are considered as potential CR accelerators from the collective action of multiple shocks from supernovae and the winds of massive stars [2][3][8][9][10]. The young ages of Cyg OB2 and NGC 6910 allow the production of very few supernovae, if any, but the wind-powered magnetic turbulence in the cocoon, with a typical energy-containing scale of 10 pc, can efficiently confine and accelerate CRs with an energy distribution in agreement with the γ-ray data [1]. It leads to diffusion lengths 100 times shorter than in the quiet interstellar medium [1], so protons can remain confined over 100 kyr in agreement with CR isotopic abundances that indicate that heavy CR nuclei are synthesized by Wolf-Rayet stars 100 kyr before their acceleration [11]. The cocoon environment may be an active CR superbubble.

In summary, the cavities carved by the winds and ionization fronts from the young stellar clusters in Cygnus X form a cocoon of freshly accelerated CRs. It provides evidence for the long advocated hypothesis that OB associations host CR factories. It provides a test case to study the impact of wind-powered turbulence on CR diffusion and its potential for in situ CR production and to re-energize Galactic CRs passing by. It sheds a new light on the TeV detections of molecular clouds that shelter outstanding stellar clusters in the Galaxy. Further spectro-imaging at GeV to TeV energies could point either to the direction of a single accelerator or to a more diffuse acceleration process within the superbubble.

[Fig. 1]





[Fig. 2]

[Fig. 1] - Maps in Cygnus X of the γ-ray excess detected in the 10-100 GeV band (left, from LAT) and of the 8 µm emission from PDRs (right, from MSX). The γ rays reveal young cosmic rays diffusing in the ionized cavities carved by numerous OB associations (white stars) and bounded by the PDRs. The green circle marks the location of the γ Cygni supernova remnant. © NASA/DOE/Fermi LAT/I. Grenier/L. Tibaldo

[Fig. 2] - Energy spectrum of the LAT cocoon emission (data points) and the Milagro flux (open circle). The curves show the expectations from the old Galactic cosmic-ray population pervading the ionized gas for different densities (blue), or upscattering the intense stellar and infrared light in the region (red). More details in [1]. © Ackermann et al. [1]

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